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Forest Soil Collembola. Do tree introductions make a difference?

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Summary. In Portugal, autochthonous forests have been gradually replaced by exotic tree species. Riparian areas are, because of their *sui generis* characteristics, places where this replacement has been more notorious. Assuming that tree species, with similar chemical composition, support similar soil arthropod communities, this study aimed to evaluate if tree species replacement would affect soil Collembola populations. Therefore, Collembola populations from areas where the introduced *Eucalyptus globulus* and *Acacia dealbata* were dominant were compared with those from native *Alnus glutinosa* and *Populus nigra* stands. *Alnus glutinosa* and *Acacia dealbata* are nitrogen fixing species whereas leaves of *Eucalyptus globulus* and *Populus nigra* have been referred by some authors as having low food value. No significant differences were detected among tree species in terms of number of taxa. However, stands of poplar and eucalyptus had significantly lower densities of Collembola than alder and acacia. The results suggest that the geographical origin of tree species is relatively unimportant for soil biota and that Collembola soil communities may be controlled by leaf chemistry and soil physical and chemical characteristics.

Key words: Collembola, acacia, eucalyptus, reafforestation

Introduction

Invasion by plants is one of the most important environmental problems in riparian areas (Pautou & Décamps 1985; Vitousek 1986). They are likely to affect ecosystem productivity, decomposition, nutrient cycling or relationships among organisms. If invading plants are not so different from the natives, the consequences of invasion are less clear (Vitousek 1986).

In Portugal, the area afforested with Australian species, such as *Eucalyptus globulus*, *Acacia longifolia* and *Acacia dealbata*, has recently increased dramatically. The latter species occurs frequently in riparian zones, traditionally occupied by other species such as *Alnus glutinosa* and *Populus nigra*. *Alnus glutinosa* (alder) and *Acacia dealbata* are nitrogen fixing species. *Populus nigra* (poplar) and *Eucalyptus globulus* both have comparatively lower concentrations in nitrogen.

Collembola are representative indicators of environmental conditions in soils (Ponge & Prat 1982; Arbea & Jordana 1985; Pozo et al. 1986). Several studies have shown that collembolan populations in Portuguese native forests (*Pinus pinaster, Quercus suber, Quercus ilex ballota*) were more diverse and had higher species richness than plantations of introduced *Eucalyptus globulus* (Figueiredo et al. 1985; Gama et al. 1989, 1991; Sousa & Gama 1994).

The aim of this work was to test whether collembolan communities of native forests, *Alnus glutinosa* and *Populus nigra*, differ from those of *Eucalyptus globulus* and *Acacia dealbata* forests.

Materials and Methods

Sites description and sampling

Soil invertebrates were sampled in eucalyptus, acacia, alder and poplar stands, in the floodplain of the lower Mondego river, central Portugal. All sites had a calcareous soil and a poor herbaceous layer composed, in most cases, of Gramineans. In the alder stands there was also an association with *Urtica dioica* and *Rubus* sp. Among the acacia stands only one site had an herbaceous layer which was composed of *Tradescantia albiflora*. A shrub layer, composed of *Ulex europaeus*, was present only in the eucalyptus stands.

Five stands of each tree species were sampled in December 1993. In each stand four samples (250 cc in volume with an area of about 100 cm^2 and a depth of about 2.5 cm) were randomly taken in the organic horizon and four samples in the corresponding mineral horizon, making a total of 80 samples per horizon (20 for each tree species). Simultaneously, soil temperature and organic horizon thickness were measured. Relative humidity in the organic horizon was also measured using a portable meter.

Fauna were extracted using Berlese-Tullgren funnels, sorted under a binocular microscope and identified to species level. After extraction, the remaining air-dried samples were crushed and sieved through a 2 mm sieve and organic mater content (Ash Free Dry Weight) was measured according to Dewis & Freitas (1984) and the pH determinated (in water, 1:6 v/v, at 20 °C).

In each stand senescent leaves were picked and the corresponding contents of nitrogen and polyphenols measured using the Kjeldahl method (Dewis & Freitas 1984) and that of Rosset et al. (1982), respectively.

Data analysis

Multiple comparisons ANOVA was used when data had a normal distribution. When this was not the case even after transformations, the Kruskal-Wallis test was used. Interbiotope chemical and physical differences were tested using a Kruskal-Wallis test followed by the non parametric equivalent of the Tukey type test (Zar 1984) to examine differences between stands. Collembolan abundances and number of taxa of the diferent sites were compared using a nested ANOVA (Zar 1984). For each site, species diversity, evenness and species richness were calculated using the Shannon-Weaver, Pielou and Margalef indices respectively. Diversity indices were compared using one-way ANOVA (Magurran 1991).

Results

Except for poplar forests, sampling sites were similar in terms of physical and chemical characteristics (Table 1). Leaves of acacia and alder had higher nitrogen content than those of poplar and eucalyptus. On the other hand acacia and eucalyptus had higher polyphenolic contents than alder and poplar (Table 2).

A total of 27348 specimens distributed over 94 taxa were identified (Table 3). The four biotopes differed significantly in terms of collembolan abundance in soil and litter ($F = 4.56$, $P < 0.01$). Higher numbers were observed in acacia (489 specimens per sampling point; cumulative volumes for soil and litter) and alder (384) than in poplar (249) and eucalyptus stands (229) (Fig. 1a). However, no significant differences were found in the number of taxa, diversity, species richness or evenness among the four biotopes ($F = 1.527$, $P > 0.05$; Fig. 1b, Table 3).

Comparisons of all pairs of stands revealed that between 49–55 % of the taxa were shared between sites. Nevertheless, 18 out of 94 taxa were found exclusively in introduced tree stands, whereas 17 taxa were found exclusively in native stands (Table 3).

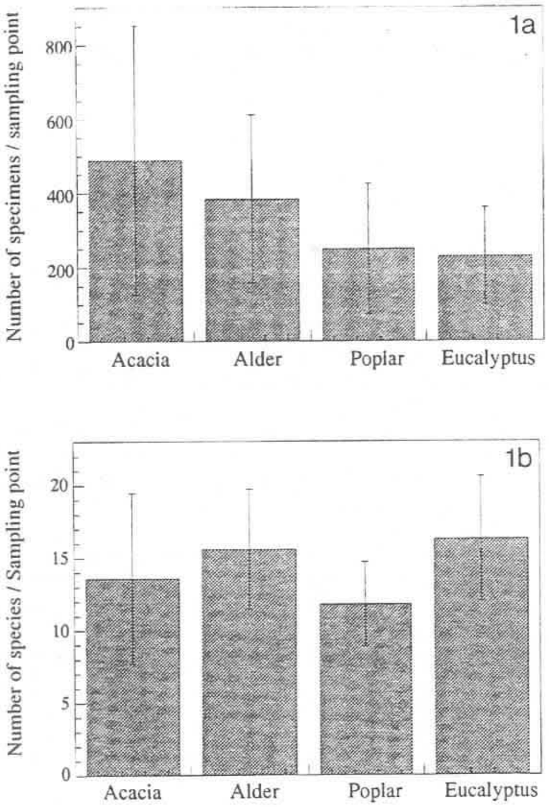

Fig. 1. (a) Abundance and (b) species richness (average ± SD) of Collembola in stands of acacia, alder, poplar and euclyptus. One sampling point corresponds to one sample of organic horizon and the corresponding mineral horizon

Table 1. Physical and chemical characterization of study sites (mean ± SD). * $p < 0.05$; n.s. – non significant. (Kruskal-Wallis test). Po – *Populus nigra*; Al – *Alnus glutinosa*; Ac – *Acacia dealbata*; Eu – *Eucalyptus globulus*

	A. dealbata	*A. glutinosa*	*P. nigra*	*E. globulus*	
Humus horiz. thickness (cm)	1.68 ± 1.0	1.38 ± 0.9	0.65 ± 1.0	1.75 ± 1.1	* Po≠Al=Ac=Eu
Soil pH	6.7 ± 0.8	6.8 ± 0.8	7.5 ± 0.2	6.1 ± 0.8	* Po≠Al=Ac=Eu
Min. horiz. temperature (°C)	14.25 ± 1.9	11.92 ± 0.8	13.63 ± 1.2	13.87 ± 2.1	* Al≠Ac=Eu=Po
Org. horiz. relative humidity (%)	9.36 ± 0.3	9.61 ± 0.25	9.46 ± 0.24	9.37 ± 0.25	n.s.
% Org. matter (Min. horiz.)	17.11 ± 15.9	9.82 ± 5.7	8.8 ± 6.1	12.5 ± 8.6	n.s.
% Org. matter (Org. horiz.)	48.97 ± 15.4	40.48 ± 19.1	26.06 ± 12.6	41.69 ± 8.4	* Po≠Al=Ac=Eu

Table 2. Polyphenols and nitrogen contents in the senescent leaves of acacia, alder, poplar and eucalyptus

	A. dealbata	*A. glutinosa*	*P. nigra*	*E. globulus*
Polyphenols (%)	6.5 ± 2.1	1.04 ± 0.5	1.4 ± 0.6	6.4 ± 2.2
Nitrogen (%)	3.8 ± 0.3	3.16 ± 0.6	1.35 ± 0.3	1.22 ± 0.1

Table 3. Total number of Collembola in the four biotopes. In all the biotopes each of the five sampling sites corresponds to a total soil volume of 2 dm³. * Exclusive species of introduced tree stands; ** Exclusive species of native tree stands

	A. dealbata					*E. globulus*					*A. glutinosa*					*P. nigra*				
	IV	III	II	I	V	I	V	II	III	IV	V	III	I	II	IV	V	III	IV	II	I
TAXA																				
**Hypogastrura vernalis* (Carl, 1901)	6																			
**Pseudachorutes palmiensis* Börner, 1903)		1																		
**Onychiurus circulans* Gisin, 1957	20																			
**Onychiurus subgranulosus* Gama, 1964		1																		
**Proctostephanus madeirensis* Gama, 1959	9																			
**Lepidocyrtus cyaneus* Tullberg, 1871	16		1																	
**Xenylla schillei* Börner, 1903			1			19														
**Deutonura centralis* (Gama, 1964)		5		3		2	2	3												
**Superodontella* sp. (8+8 eyes)							2													
**Stenacidia hystrix* (Börner, 1903)									1											
**Friesea ladeiroi* Gama, 1959	79				7			1												
**Proisotoma coeca* Gama, 1961							4			1										
**Arrhopalites elegans* Cassagnau & Delamare, 1953							39													
**Stenaphorura quadrispina* Börner, 1901										2										
**Spatulosminthurus lesnei* (Denis, 1925)					2			1												
**Ceratophysella tergilobata* Cassagnau, 1954										1										
**Xenyllodes armatus* Axelson, 1903							12													
**Lipothrix lubbocki* (Tullberg, 1872)		4		1				3	1	2										
Xenyllogastrura octoculata (Steiner, 1955)		116			1		1				4									
Folsomia sexoculata (Tullberg, 1871)		119								1	1									
Microgastrura duodecimoculata Stach, 1922	1	87		1	6		7		88			18				1	1			
Xenylla brevisimilis mediterranea Gama, 1964	2	138	1	258	1	56	20		44	166			2	1			3			30
Ceratophysella engadinensis (Gisin, 1949)	222	1		18		103			109	6		1	1	75				229		1
Mesaphorura sp.	40	185	145	276	206	59	41	7	84	22	8	23	12	7	286	22	2	7	42	100
Friesea claviseta Axelson, 1900	1	47	1			27	5	85		1				1						
Micranurida sp. (2+2 eyes)	19	176	3	42	3	3	213		89		1	24		5	67	49	1			29
Protaphorura armata (Tullberg, 1869)	27	320		81	85		12		4	3	2	2	1	2	4		2	1		22
Cryptopygus scapelliferus (Gisin, 1955)	44		26	41			37		186	11	17					53				
Pseudachorutes sp.	6				8											69				
Cryptopygus thermophilus (Axelson, 1900)	3	64	1798	480	467	56	1	274	53	2	1	1	391	10		360	4		816	146
Isotomiella minor (Schäffer, 1896)	104			8		9	1		95		1	180	3		174		1		27	39
Parisotoma notabilis (Schäffer, 1896)	76		193	123	93	6	179	4	58		86	86	814	619	1410	319	45	14	55	414
Megalothorax minimus Willem, 1900	22	25		40		1	23		91	1	26	399	198	122	246		2	1	3	65
Heteromurus major Moniez, 1889	4	17	1	12		30	74	15	40	19	35	34	33	173	56	75	14	20	7	15
Lepidocyrtus paradoxus Uzel, 1890	2												2			3	4	2	1	

Sphaeridia pumilis (Krausbauer, 1898)	1	3	8	6	24	141	18	60	110		184	50	53	218	58	26	55	84	121	68
Pseudosinella picta Börner, 1903	1		2	23		1	1	7	1			2	1	2					1	47
Sminthurinus elegans (Fitch, 1863)	2								1		1	1	2	12	45		55		8	2
Anurida pusilla Gama, 1964		17		21			13		11	1					1					4
Bilobella aurantiaca (Caroli, 1912)		11		5		2	22		17	5		4								
Deutonura portucalensis (Gama, 1964)		1		5						14		17			13					13
Endonura colorata (Gama, 1964)		3		3													1			
Pseudachorutes parvulus Börner, 1901		34				6	52			10	1									17
Pseudachorutes subcrassus Tullberg, 1871			4	20		84			61								19		3	
Onychiurus silvarius Gisin, 1952		11		122		57			40	39		209								
Cryptopygus debilis (Cassagnau, 1959)		2478		87	813		119			3			2			20	3		2	530
Folsomia quadrioculata (Tullberg, 1871)			44	1		1		311			1	1								
Proisotoma gisini Gama, 1964			1	1					64	9			1							15
Entomobrya multifasciata (Tullberg, 1871)		1			1		20	10				2	2	5	3	5	4	6		1
Lepidocyrtus lusitanicus Gama, 1964		1		5					2				1	1						1
Entomobryidae juv.				27				2					13	12	6		23	7	3	
Tomocerus vulgaris (Tullberg, 1871)		8					1	5		1	2				1		1			
Neelus murinus (Folsom, 1896)				10								3			4					
Allacma fusca (Linnaeus, 1758)		4													1					
Dicyrtomina minuta (Linnaeus, 1767)		3		5		19	10	43		11		11								34
Dicyrtomina ornata (Nicolet, 1841)									2		58	4		5			1			
Isotomodes trisetosus (Denis, 1928)				1															8	3
Isotomurus fucicola (Reuter, 1891)						8	29		4	8	9	1			1		1		1	
Isotomurus palustris bimaculatus Agren, 1903							2											28		
Brachystomella parvula (Schäffer, 1896)			1		10	3				8		1		9				2	1	
Proisotoma richardi Denis, 1924	1																	29		
Stenognathellus denisi Cassagnau, 1953				8		19			1			2	1	10						
Deutonura phlegraea (Caroli, 1912)				4		1					19		17	113	2					8
Ceratophysella armata (Nicolet, 1841)					1	7	87	1		1		33			12					
Xenylla maritima Tullberg, 1869							7							20						
Pseudachorudina bougisi Delamare, 1951										45		2								
Dicyrtomina saundersi (Lubbock, 1862)					2			2					1	58		19				
Sminthurides parvulus (Krausbauer, 1898)						71		5	65	6		14								
Sminthurinus aureus (Lubbock, 1862)					23		5				4				2	148	10	80		
Proisotoma minuta (Tullberg, 1871)							12		2	1	3	14	17		10			89	9	1
Tetracanthella hygropetrica Cassagnau, 1954										128				2						
Tomocerus minor (Lubbock, 1862)							2				67			15						
Arrhopalites caecus (Tullberg, 1871)						1				1										3
Arrhopalites sericus Gisin, 1947									2			1		1						
Caprainea bremondi (Delamare & Bassot, 1957)						5	2		3	2		5			4				1	
Superodontella carmenae Arbea & Luciáñez, 1991							2								8					
Sminthurinus bimaculatus (Axelson, 1902)									1			1					5			
**Deutonura deficiens sylvatica* Deharveng, 1982												9								

Table 3. Fortsetzung

	A. dealbata					*E. globulus*					*A. glutinosa*					*P. nigra*				
	IV	III	II	I	V	I	V	II	III	IV	V	III	I	II	IV	V	III	IV	II	I
***Friesea mirabilis* (Tullberg, 1871)															9					
***Neanura muscorum* (Templeton, 1835)												20	1		12					
***Protaphorura gisini* (Haybach, 1960)													24							
***Protaphorura hortensis* (Gisin, 1949)															6					
***Isotomurus aquatilis* (Müller, 1776)											96									
***Oncopodura crassicornis* Schoebotham, 1911													8	35						
***Pogonognathellus flavescens* (Tullberg, 1871)												1	5							
***Pogonognathellus longicornis* (Müller, 1776)												12		8	1					
***Sminthurides aquaticus* (Bourlet, 1841)											1									
***Xenylla grisea* Axelson, 1900											3		7			147		21		10
***Folsomia candida* Willem, 1902											15				1			20	3	
***Pseudosinella sexoculata* Schött, 1902													1							1
***Anurida granaria* (Nicolet, 1847)												4			41					
***Hypogastrura assimilis* Krausbauer, 1898																		1		
***Isotoma olivacea* Tullberg, 1871																		39		
***Pseudosinella infrequens* Gisin & Gama, 1969																1				2
Number of individuals	708	3881	2230	1738	1753	798	1081	834	1331	532	644	1192	1614	1536	2489	1317	257	680	1112	1621
Number of taxa	*24*	*29*	*16*	*33*	*18*	*29*	*36*	*18*	*32*	*32*	*25*	*36*	*28*	*26*	*30*	*16*	*23*	*19*	*19*	*28*
Species diversity	3.27	2.21	1.10	3.45	2.19	3.82	3.94	2.40	4.09	3.32	3.27	3.26	2.21	2.95	2.38	2.99	3.32	3.13	1.56	3.10
Evenness	*0.71*	*0.46*	*0.28*	*0.68*	*0.53*	*0.79*	*0.76*	*0.58*	*0.82*	*0.66*	*0.70*	*0.63*	*0.46*	*0.63*	*0.48*	*0.75*	*0.73*	*0.74*	*0.37*	*0.65*
Species richness	3.50	3.39	1.95	4.29	2.28	4.19	5.01	2.53	4.31	4.94	3.71	4.94	3.66	3.41	3.71	2.09	3.96	2.76	2.57	3.65

Discussion

Collembolan communities in stands of introduced and native trees did not differ in terms of number of taxa or in the percentage of co-occurring species. However, similar works have previously demonstrated that collembolan communities from eucalyptus forests have lower number of species than the reference pine or oak forests (Gama et al. 1994; Sousa & Gama 1994; Vasconcelos et al. 1994). The results of this study suggest that leaf chemistry may be an important factor controlling the structure of soil collembolan communities. The relatively lower number of Collembola in the poplar and eucalyptus soils and the higher numbers in acacia and alder could be chiefly explained by the differences in terms of the chemical composition of the leaves, namely, the corresponding nitrogen contents. In fact, nitrogen has been identified as a limiting factor to detrital based systems (Begon et al. 1990) and in this study tree species with higher nitrogen concentration in the leaves had higher abundances of Collembola (alder and acacia).

However, other factors such as depth of the litter layer and organic matter content (Gama et al. 1995) may also be considered. Some of the chemical and physical soil characteristics may be a consequence of the tree species. Litter with high proportions of refractary compounds is expected to decompose slowly leading to the accumulation of organic matter in the soil. Actually, in spite of the greater depth of the litter layer and the higher content of organic matter, eucalyptus stands had a lower density of Collembola which is consistent with previous studies (Gama et al. 1994; Sousa & Gama 1994; Vasconcelos et al. 1994). This could be attributed to the low quality of detritus with a relatively low nitrogen concentration and high polyphenolic content in the leaves (Pereira 1995 – mimeograph).

Therefore, the geographical origin of tree species seems to be relatively unimportant in determining the biodiversity of soil communities but chemical characteristics of the leaves may be important, influencing directly or indirectly (soil organic matter content, timing of leaf input, etc.) the structure of the soil collembolan communities.

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